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# 1. INTRODUCTION

**Project Title:** NSLS-II Experimental Tools (NEXT)

**Project Location:** Brookhaven National Laboratory

**Description of Project:** The goal of the NEXT project is to provide NSLS-II with five additional “best-in-class” beamlines, and the design and engineering for a sixth beamline. Developing these beamlines, which will provide advanced experimental capabilities complementary to those provided by the six initial NSLS-II Project beamlines in a timely manner, enhances the ability of the new NSLS-II facility to enable scientific breakthroughs needed to achieve a secure and sustainable energy future. They will support the urgent needs identified by the U.S. research community for responding to the DOE mission of achieving transformational energy solutions in the near-term while simultaneously expanding our knowledge of fundamental energy science. The NEXT project will also provide a significant capacity in the early years of NSLS-II operations to support the wide-ranging research programs of the existing NSLS user community. It will increase the number of users that NSLS-II can support by about 300 to 400 users per year.

**Cost:**

Date	OPC (\$M)	TEC (\$M)	Contingency (\$M)	TPC (\$M)
At CD-2	\$3.0M	\$65.1M	\$21.9M	\$90.0M
At CD-4	\$3.0M	\$86.3M	\$ 0.7M	\$90.0M

**Schedule:**

Critical Decision	Date at CD-2	Date at CD-4
CD-0 – Approve Mission Need	May 2010 (actual)	May 2010 (actual)
CD-1 – Approve Alternative Selection & Cost Range	December 2011 (actual)	December 2011 (actual)
CD-2 – Approve Performance Baseline	October 2013 (actual)	October 2013 (actual)
CD-3 – Approve Start of Construction	July 2014 (actual)	July 2014 (actual)
Early Project Completion	September 2016 (planned)	July 2017 (planned)
CD-4 – Project Complete	September 2017 (planned)	September 2017 (planned)
Schedule contingency	12 months	2 months

**Funding Profile (in \$M):**

	FY11	FY12	FY13	FY14	FY15	FY16	Total
OPC	3.0						3.0
TEC – Design		3.0	2.0				5.0
TEC -- Fabrication		9.0	10.0	25.0	22.5	15.5	82.0
TPC	3.0	12.0	12.0	25.0	22.5	15.5	90.0

## 2. OVERALL PROJECT

This section describes significant success lessons and areas of potential improvement for the overall NEXT Project. Impacts and suggested solutions are also provided. Other Lessons Learned are detailed in the subsequent sections, grouped in 6 subject areas: Project Management, Human Resources, ES&H, Procurement, QA, and Engineering and Design.

### 2.1 Success Lessons

Lessons Learned— Successes	Description, Impacts, and Solutions
NSLS-II Project lessons learned adopted by NEXT	<ul style="list-style-type: none"> <li>A significant number of lessons learned by the NSLS-II Project were communicated to and adopted by NEXT, in all areas of this document.</li> </ul>
Strong support from NSLS-II, Energy and Photon Sciences Directorate, and BNL	<ul style="list-style-type: none"> <li>NSLS-II, Energy and Photon Sciences Directorate, and the laboratory delivered strong support to NEXT in all areas, including Management, ESH, QA, Project Controls, Procurement, and Human Resources.</li> <li>Organizational change of NSLS-II in summer 2014 to create the Project Management group provided management support and needed horizontal integration of WBS and resources common to all beamlines (utilities, safety systems, controls)</li> </ul>
Successfully recruited and retained key staff	<ul style="list-style-type: none"> <li>NEXT was approved to use the HR Toolkit set up for the NSLS-II Project, including enhanced sign-on capabilities and performance-based incentive pay options for key project personnel.</li> <li>The incentive program was an important tool for attracting and recruiting key project personnel.</li> </ul>
Revision of schedule allocation for procurement process	<ul style="list-style-type: none"> <li>See “Insufficient schedule allocation for procurement process” in Lessons Learned – Potential Improvements” below; the resource loaded schedule initially formulated for NEXT did not include sufficient schedule durations for the procurement process.</li> <li>As a result, procurement schedule duration, from pinning to award, was increased by approx. 20 working days in May 2014, affecting all future major procurements.</li> <li>The revised procurement activity strings should be utilized for future major procurements.</li> </ul>
Improvements in scheduling and tracking of major procurements	Procurement process was re-evaluated, as described above. In addition, tools were developed to track procurements more closely. As a result, more realistic procurement schedules were attained, helping to maintain overall project schedule.
Significant post-CD-3 scope additions, directed by BHSO	Scope additions were good for beamline performance but disruptive to project management. Robust real-time response, including diligent documentation of added scope and resultant cost/schedule changes, was successful.
Diligent monthly accounting of accruals is needed to understand cost performance	<ul style="list-style-type: none"> <li>EV and Accruals must either match each month or the discrepancy must be taken into account. Otherwise accrual gaps mask cost performance.</li> <li>Analysis tools were developed to determine true cost performance each month</li> </ul>

Lessons Learned— Successes	Description, Impacts, and Solutions
Continuous attention required to minimize cost growth	<ul style="list-style-type: none"> <li>EAC growth is typical, often driven by labor cost growth.</li> <li>The project controlled cost growth by assessing EAC frequently, without padding. Total NEXT labor cost growth from CD-2 baseline to end of project was 13% of EAC.</li> </ul>

## 2.2 Areas of Potential Improvements

Lessons Learned— Potential Improvements	Description, Impacts, and Solutions
Overly aggressive resource-loaded schedule	<ul style="list-style-type: none"> <li>The NEXT resource-loaded schedule was revised in fall 2012 to pull forward activity strings in nearly all Level 2 WBS elements. Many of these activities then ended up being completed 1-2 months late, reducing the cumulative EVMS schedule index.</li> <li>For future projects, the resource-loaded project schedule developed for baselining (CD-2) should be realistically achievable and not forced to be shorter in duration in order to conform to external constraints such as funding profiles or carryover predictions. Shifting schedule too early within a fixed overall project duration increases the likelihood of schedule slippage early in the project, when performance expectations are being monitored closely.</li> </ul>
Insufficient schedule allocation for procurement process	<ul style="list-style-type: none"> <li>Resource loaded schedule initially formulated did not include sufficient schedule durations for the procurement process.</li> <li>This shortfall consumed schedule contingency in some cases (others gained schedule float via shorter-than-estimated contracted delivery times).</li> <li>See “Revision of schedule allocation for procurement process” in Lessons Learned – Successes above.</li> </ul>
Complexity not fully captured in baseline cost.	<ul style="list-style-type: none"> <li>Complexity of SIX beamline (equivalent to 2 beamlines: photon delivery system + endstation) not fully captured in baseline schedule, cost, and risk. Added both schedule and cost.</li> <li>This complexity was a major cause of the schedule delay experienced for the final M&amp;S component of NEXT: the SIX endstation Triple Rotation Flange (TRF). Complexity of the SIX spectrometer, as well as that of the photon delivery systems for the soft x-ray beamline (ESM and SIX), led to major delays in engineering and design of the TRF. All of this scope for NEXT was provided by a single contractor. Concern regarding the magnitude of this combined scope was known and acted upon relatively early on, but lack of progress on one component (the TRF, a relatively small value fraction of the total) did not occur until relatively late, thereby delaying achievement of the NEXT Early Project Completion milestone.</li> </ul>

### 3. PROJECT MANAGEMENT

#### 3.1 Success Lessons

Lessons Learned— Successes	Description, Impacts, and Solutions
Best practices for EVMS implementation, schedule building & maintenance, and risk	<p>The following best practices were implemented by NEXT:</p> <ul style="list-style-type: none"> <li>• EV backloading of procurement contract activities prior to award</li> <li>• Usage of percent-complete EV technique and linear EV loading wherever appropriate</li> <li>• Usage of appropriate procurement strings, with key milestones (PPM handoff, award) implemented uniformly</li> <li>• Budgeting sufficient resources and durations for specification writing</li> <li>• Limiting number of activities per WBS, so that CAMs can fully understand and manage scope (add CAMs as needed)</li> <li>• Regular monitoring of look-ahead schedules to identify potential schedule issues proactively</li> <li>• Provision of sufficient project controls support</li> <li>• Identify procurement bottleneck items by float on an ongoing basis</li> <li>• Plan for and include resources for reviews, reporting, and documentation in the resource-loaded project schedule</li> <li>• Regularly revise working schedule durations and logic, even spanning CAMs, to maintain a realistic working schedule for projection purposes</li> <li>• Implement best risk management practices: learn from NSLS-II Project, maintain good time-stamped records for later use</li> <li>• Direct PM involvement in monthly EV process</li> <li>• Development of convenient I/O tools for P6, typically Excel-based</li> </ul>
Staffing resource coordination	<ul style="list-style-type: none"> <li>• Beamline staffing experience from the NSLS-II Project was used to establish NEXT beamline resource estimates. Examples: <ul style="list-style-type: none"> <li>○ The peak engineering and design resource levels in FY14 were maintained for FY15 and FY16</li> <li>○ Effort to install and test Common Beamline Systems, esp. PPS and EPS, was increased based on NSLS-II Project experience</li> </ul> </li> <li>• Common Systems was determined to require multiple CAMs: one at WBS Level 2, two at Level 3 (implemented 3Q FY14)</li> <li>• Integrated Staffing Plan is being utilized to plan pooled resources across projects, such as electricians, technicians, and designers.</li> </ul>
Project Management Tools inherited from NSLS-II and utilized to good advantage	<ul style="list-style-type: none"> <li>• Early preparation and posting of project management documents, clearly defining roles and decision making processes, authorities, thresholds</li> <li>• NEXT was approved to use the HR Toolkit set up for the NSLS-II Project, including enhanced sign-on capabilities and performance-based incentive pay options for key project personnel.</li> <li>• Risk Management: establishment of the Risk Management Team, establishment and usage of the NEXT Risk Registry / risk assessment matrix, and regular reassessment of project risk</li> </ul>



Lessons Learned— Successes	Description, Impacts, and Solutions
	<ul style="list-style-type: none"> <li>Establishment and regular updating of a prioritized contingency spend plan</li> <li>Effective usage of adopted project management tools such as EVMS and Risk Registry</li> <li>Clearly documented project assumptions maintained throughout the life of the project</li> <li>Usage of 90-day look-ahead schedules for monitoring upcoming work and provide timely flagging of potential schedule issues</li> <li>Implementation of periodic (monthly or more frequent) schedule status reports from suppliers</li> <li>Coaching of CAMs to refresh and reinforce their knowledge of cost &amp; scheduling tools, esp. EVMS</li> <li>Co-location of project controls staff with the project team. Note: this lesson was “un-learned” in 4QFY14 when, owing to necessary space reassignments, project controls staff were re-located to a different building.</li> </ul>
Deputy Manager needed for project of this size & complexity	<p>Jeff Keister accepted Deputy PM assignment fall 2013. His roles included:</p> <ul style="list-style-type: none"> <li>Risk updating and analysis</li> <li>Development and usage of accrual analysis tools</li> <li>Important contributions to management of 10 Level 2 WBS elements</li> </ul>

### 3.2 Potential Improvements

Lessons Learned— Potential Improvements	Description, Impacts, and Solutions
Overly aggressive resource-loaded schedule	<ul style="list-style-type: none"> <li>The NEXT resource-loaded schedule was revised in fall 2012 to pull forward activity strings in nearly all Level 2 WBS elements. Many of these activities then ended up being completed 1-2 months late, reducing the cumulative EVMS schedule index.</li> <li>For future projects, the resource-loaded project schedule developed for baselining (CD-2) should be realistically achievable and not forced to be shorter in duration in order to conform to external constraints such as funding profiles or carryover predictions. Shifting schedule too early within a fixed overall project duration increases the likelihood of schedule slippage early in the project, when performance expectations are being monitored closely.</li> </ul>
Overly detailed Level 2 resource-loaded schedule	<ul style="list-style-type: none"> <li>The resource-loaded scheduled for Common Systems (WBS 2.03) suffered from too much complexity, which was replicated for each beamline rather than consolidated. There were good reasons for the architecture of WBS 2.03 and the level of detail was seen as demonstration of scope coverage, but ended up being rather difficult to manage.</li> <li>Future projects should simplify Common Systems schedule logic while retaining interfaces/links to other WBS and Common Systems activities in other projects in Photon Sciences.</li> </ul>

Lessons Learned— Potential Improvements	Description, Impacts, and Solutions
Need for well-defined Level 2 scope and interfaces	<ul style="list-style-type: none"> <li>Each Level 2 WBS manager needs to understand their own Level 2 scope and interfaces to any other Level 2 scope, early in the project. For NEXT, the scope definitions of Common Systems and Controls with respect to the beamline WBS's was not completely delineated early in the project. This can lead to over- or under-estimated M&amp;S and labor estimates.</li> </ul>
Need for policies and procedures early in the project	<ul style="list-style-type: none"> <li>Some policies and procedures were not available early in the NEXT project, e.g. Bremsstrahlung and x-ray ray tracing policies, procedures, or guidance. The result was duplication and/or repetition of effort that was expended in advance of final determination of beamline shielding requirements, in order to maintain project completion prior to the CD-4 deadline.</li> <li>Lack of manpower in the ES&amp;H group to complete beamline shielding calculations according to the schedule needed for NEXT had the same effects: schedule delays from duplication or repetition of effort.</li> </ul>
Better define scope for major procurements	<ul style="list-style-type: none"> <li>Statements of Work (SOWs) for major procurements should better define standard interfaces for work that must be performed in-house by BNL staff, including: rigging, survey, and carpentry.</li> <li>Major procurement contracts should not include effort that can be better or more efficiently performed by in-house staff.</li> </ul>
Labor efficiency factors	<ul style="list-style-type: none"> <li>Bottom-up labor estimates for NEXT assumed, in most cases, 100% labor efficiency. That is, they generally did not include the time required for preparation, setup, cleanup, and other time spent not directly providing the estimated effort. Time-tested average labor efficiency is ~80%, leaving a shortfall of ~20% above and beyond touch-labor. This factor should be applied to all labor activities, including those based on historical cost and schedule.</li> <li>Labor shortfalls in NEXT were captured via PCRs. For future projects, approx. 20% should be added to effort estimates to cover labor inefficiencies.</li> <li>Priority given to IRRs is helpful in many ways, but caution should be exercised to avoid an “emergency” situation in which technical effort in support of an IRR may be inefficient owing to last minute purchases of small M&amp;S items (see credit card item below) and “standing army” inefficiency while waiting for parts to arrive</li> </ul>
Beamline engineering roles	<ul style="list-style-type: none"> <li>Should have a single point-of-contact engineer per beamline</li> <li>For future projects, consider separating CAM and scientist duties for beamline WBS elements. Engineers may be a good match to the CAM duties, freeing up scientists to complete their inputs to the design process earlier, thereby advancing their subsequent project work</li> </ul>
Maturation of cost estimation tools and experience	<ul style="list-style-type: none"> <li>Conversion from Cost Estimating Database version 1 to version 2 was performed contemporarily with preparation of cost estimates for NEXT. Resultant delays were one driver for delay in achieving CD-2 approval.</li> <li>Another contributor to the lack of maturity in NEXT cost estimates was</li> </ul>



Lessons Learned— Potential Improvements	Description, Impacts, and Solutions
	<p>the fact that the NSLS-II project beamlines were still gaining experience when NEXT estimates were being developed.</p> <ul style="list-style-type: none"> <li>• Standard beamline cost estimating metrics should be agreed to and uniformly utilized. These metrics include: drawings (designer), survey points (survey), vacuum sections (vacuum, technician), granite blocks (rigging, carpentry), motor axes (controls), optics (metrology).</li> </ul>
Usage of credit cards	<ul style="list-style-type: none"> <li>• Issues inherent to the convenience provided by usage of credit cards               <ol style="list-style-type: none"> <li>(1) Management review of all purchases is impractical</li> <li>(2) Credit card purchases are widely used to procure small items that were not planned in the cost estimate; the total amount spent can be significant</li> </ol> </li> <li>• For future projects, consider imposition of limits credit card charges. Options include monthly caps or cards with specified total authorization</li> </ul>
Schedule slippage from competing for resources in a matrixed organization	<p>Prioritization of a given project cannot be 100% in a matrixed organization with multiple internal customers, leading necessarily to schedule delays for specific tasks. Delays for one beamline can propagate to another beamline, creating a complex effect on the overall project schedule.</p> <ul style="list-style-type: none"> <li>• Opportunities also exist to utilize “troughs” in resource demand to advance project schedule. Real-time, on-demand scheduling of support services is key to minimizing schedule delays during installation.</li> </ul>
Increased granularity could improve risk assessment	<ul style="list-style-type: none"> <li>• Could use 5x5 or 5x3 risk-assessment (likelihood, impact) matrices, instead of 3x3</li> <li>• Ensure that risk items with &gt;70% likelihood are included in EAC</li> </ul>

## 4. HUMAN RESOURCES

### 4.1 Success Lessons

Lessons Learned— Successes	Description, Impacts, and Solutions
Successfully recruited and retained key staff	<ul style="list-style-type: none"> <li>NEXT was approved to use the HR Toolkit set up for the NSLS-II Project, including enhanced sign-on capabilities and performance-based incentive pay options for key project personnel.</li> <li>The incentive program was an important tool for attracting and recruiting key project personnel.</li> </ul>
Dedicated recruiters	<ul style="list-style-type: none"> <li>A team of recruiters dedicated to Photon Sciences recruiters was co-located with NEXT project staff through CD-2, at which point all scientific and engineering hires were complete.</li> </ul>
Effective project management training of staff	<ul style="list-style-type: none"> <li>Cost Account Managers (CAMs) for the project were required to take and maintain a number of project management training courses, including EVMS and procurement contract technical representative training.</li> </ul>
Co-location of technical and support personnel	<ul style="list-style-type: none"> <li>Technical staff and project support staff (project controls, procurement, HR, budget, ESH, and QA) who were working on the same areas or tasks were co-located in the same or near-by building as much as possible as this makes communication much easier and faster.</li> </ul>
Integrated staffing plan	<ul style="list-style-type: none"> <li>Integrated Photon Sciences staffing plan was developed by 3Q FY2012, including staff for all projects as well as operations.</li> <li>This plan serves as a resource management tool, which is needed especially for matrixed support staff.</li> </ul>

### 4.2 Potential Improvements

Lessons Learned— Potential Improvements	Description, Impacts, and Solutions
Delays connected with underperforming staff	<ul style="list-style-type: none"> <li>The time required to address the problem of underperforming staff, through performance improvement plans and/or termination actions, incurs schedule delays.</li> <li>It would be preferable to be able to bring in extra resources prior to completion of the above actions to maintain project schedule.</li> </ul>

## 5. ES&H

### 5.1 Success Lessons

Lessons Learned— Successes	Description, Impacts, and Solutions
ES&H policies, procedures, and culture inherited from NSLS-II Project	<ul style="list-style-type: none"> <li>• Rigorous safety culture, throughout Photon Sciences Directorate</li> <li>• ES&amp;H oversight by dedicated ES&amp;H staff, from the earliest phases of NEXT. Well defined ES&amp;H roles for NEXT project staff.</li> <li>• Strong laboratory commitment to ES&amp;H principles</li> <li>• Good level of communication between ES&amp;H staff and other project staff.</li> <li>• Clear integration of ES&amp;H requirements in procurements, especially major procurement contracts.</li> </ul>

### 5.2 Potential Improvements

Lessons Learned— Potential Improvements	Description, Impacts, and Solutions
Need for ES&H-related policies and procedures early in the project	<ul style="list-style-type: none"> <li>• Some ES&amp;H-related policies and procedures were not available early in the NEXT project, e.g. Bremsstrahlung and x-ray ray tracing policies and procedures. One result is duplication and/or repetition of effort. More importantly, uniformity in the application of these policies and procedures is then more difficult to ensure.</li> </ul>

## 6. QA

### 6.1 Success Lessons

Lessons Learned— Successes	Description, Impacts, and Solutions
Tracking system for recommendations from reviews	<ul style="list-style-type: none"><li>• A recommendation tracking system and database inherited from the NSLS-II Project was utilized to capture and track recommendations from all reviews conducted from the beginning of the project.</li></ul>
Effectiveness of traveler system	<ul style="list-style-type: none"><li>• The traveler system, inherited from the NSLS-II project, is an effective tool for capturing and tracking QA data related to the production, testing, and acceptance of technical components.</li></ul>
Frequent vendor site visits	<ul style="list-style-type: none"><li>• The practice of frequent vendor site visits was inherited from the NSLS-II Project. These visits are conducted by technical as well as QA staff and detailed site visit reports are submitted to record findings.</li></ul>

### 6.2 Potential Improvements

Lessons Learned— Potential Improvements	Description, Impacts, and Solutions
Need for more routine methods of capturing lessons learned	<ul style="list-style-type: none"><li>• To date, Lessons Learned have been captured in formal documents required by DOE 413.3B after CD-3 and after CD-4. These documents are valuable, but should be augmented and facilitated by capturing lessons learned in a database throughout the life of each project.</li></ul>

## 7. PROCUREMENT

### 7.1 Success Lessons

Lessons Learned— Successes	Description, Impacts, and Solutions
Increased schedule allocation for procurement process	<ul style="list-style-type: none"> <li>Resource loaded schedule initially formulated did not include sufficient schedule durations for the procurement process.</li> <li>This short-fall consumed schedule contingency in some cases (others gained schedule float via shorter-than-estimated contracted delivery times).</li> <li>As a result, procurement schedule duration, from pinning to award, was increased by approx. 20 working days in May 2014, affecting all future major procurements.</li> <li>The revised procurement activity strings (documented in the NEXT Assumptions document) should be utilized for future projects.</li> </ul>
Procurement support staff assigned to NEXT	<ul style="list-style-type: none"> <li>Adequate procurement support staffing level has been assigned to NEXT.</li> </ul>
Procurement Liaison Engineers	<ul style="list-style-type: none"> <li>Involvement of procurement liaison engineers throughout the procurement process, from initial suggestion of standard document templates through editing, approval, and routing to PPM.</li> </ul>
Dedicated procurement staff co-located with project team	<ul style="list-style-type: none"> <li>Procurement staff dedicated to Photon Sciences were assigned to the NEXT Project.</li> <li>These procurement staff were co-located with NEXT project staff through CD-3, in the same or a nearby building, facilitating effective communication.</li> <li>It is important that the dedicated procurement group remain stable (fixed number and minimum turnover) during the life of the project.</li> </ul>
Advanced Procurement Planning	<ul style="list-style-type: none"> <li>A practice inherited from NSLS-II is preparation of Advanced Procurement Plans (APPs) for all the major procurements in the project schedule. APPs describe the type of procurement, expected need date, dollar amount, and potential suppliers. APPs inform procurement staffing needs with sufficient lead time.</li> </ul>
Involvement of technical, QA, and ES&H staff	<ul style="list-style-type: none"> <li>Involve all relevant technical, QA, and ES&amp;H staff in contract preparation, bid evaluation and award, and contract management.</li> </ul>
Contractor selection process	<ul style="list-style-type: none"> <li>Contractors for most major procurements were selected based on “Best Value” criteria. This process does in fact ensure best value selection and results in increased satisfaction among our technical staff.</li> </ul>
Bundled procurements for economy of scale	<ul style="list-style-type: none"> <li>Cost savings from vendor due to economy of scale</li> <li>Less lab procurement resources (less travel, less personnel, less paperwork, etc.) were needed since quantity of procurements is reduced</li> <li>Improved quality of components produced resulting from increased technical interaction and oversight (two beamlines making sure that the delivered product meets requirements, rather than one)</li> </ul>

## 7.2 Potential Improvements

Lessons Learned— Potential Improvements	Description, Impacts, and Solutions
Early training and documentation of procurement processes	<ul style="list-style-type: none"> <li>• Formal training and documentation of procurement processes should be provided to all CAMs prior to CD-3A and refreshed annually.</li> <li>• Coaching on the specifics of how to write Specifications &amp; SOWs should be included in this training.</li> </ul>
Insufficient schedule allocation for procurement process	<ul style="list-style-type: none"> <li>• Resource loaded schedule initially formulated did not include sufficient schedule durations for the procurement process.</li> <li>• This short-fall consumed schedule contingency in some cases (others gained schedule float via shorter-than-estimated contracted delivery times).</li> <li>• As a result, procurement schedule duration, from pinning to award, was increased by approx. 20 working days. Implemented in May 2014, affecting all future major procurements.</li> <li>• The revised procurement activity strings should be utilized for future projects.</li> <li>• In addition, the learning process undertaken by new CAMs for their first major procurement requires more time than for subsequent procurements. For future projects, the specification and SOW preparation activities should be increased by approx. 1 month for the first major procurement for any new CAMs</li> </ul>
Coordination of major procurement schedules	<ul style="list-style-type: none"> <li>• Coordination of the procurement schedule within each project, as well as with other projects in Photon Sciences/BNL, would enable management of the bid submission schedule and would be beneficial for maximizing the number of competitive bids.</li> </ul>
Standardization of common requirements	<ul style="list-style-type: none"> <li>• Streamlining the documentation for common requirements for design and fabrication would facilitate the RFP process. Project staff and potential vendors should not have to wade through overlapping documents in order to determine facility standards.</li> </ul>



## 8. ENGINEERING and DESIGN

### 8.1 Success Lessons

Lessons Learned— Successes	Description, Impacts, and Solutions
Utilization of external design and analysis resources	<ul style="list-style-type: none"> <li>Contracting for external design and analysis resources was utilized at times of peak load on Photon Sciences engineering and design resources. This strategy enabled engineering and design activities to proceed on schedule.</li> <li>Examples include: <ul style="list-style-type: none"> <li>Finite element analysis of beamline components</li> <li>Utilities engineering and design</li> </ul> </li> </ul>
Standardization of components	<ul style="list-style-type: none"> <li>A practice inherited from the NSLS-II Project, standardization of various infrastructure (e.g. hutches) and common system components significantly benefitted installation planning and execution. This practice will also permit streamlined maintenance and spares inventories for operations.</li> <li>Horizontal integration of common system components and activities provides cost savings and schedule efficiencies.</li> </ul>
Coordinated engineering team and common design	<ul style="list-style-type: none"> <li>A good practice adopted from the NSLS-II Project, grouping of instrument engineers and beamline designers together in one team increased efficiency, uniformity, and helped share good ideas, designs, and practices.</li> </ul>
Implementation of value engineering principles	<ul style="list-style-type: none"> <li>Value engineering principles were put into practice wherever appropriate.</li> <li>These practices resulted in simpler, more reliable, components and systems at lower cost. For example: <ul style="list-style-type: none"> <li>Greatest cost savings (~\$1.2M) resulted from using single-wall construction for the SEB-II experimental hall for the SIX endstation rather than a double-wall design. Local temperature control will mitigate temperature fluctuations in a volume orders of magnitude smaller than that of the entire experimental hall.</li> </ul> </li> </ul>
Early establishment of Requirement, Specification, and Interface Documents	<ul style="list-style-type: none"> <li>Early establishment of Requirement, Specification, and Interface (RSI) documents for each beamline, especially with respect to the insertion devices and front ends was effective in ensuring clear and documented communication with all Photon Sciences divisions involved in beamline development.</li> </ul>
Interaction during design phase	<ul style="list-style-type: none"> <li>Beamline staff benefited from interaction with NSLS-II project beamline staff during the NEXT design phase, as stated in the example below. <ul style="list-style-type: none"> <li>SMI nearly attempted to procure vacuum door seals with O-rings for high vacuum sample chambers, without specifying dovetail grooves to hold the O-ring. The SMI team judged that tension would hold the ring and that the dovetail groove was an unnecessary expense. Communication with the IXS (NSLS-II Project) beamline team revealed regret for not specifying a dovetail groove for their experimental optics chamber. Their equipment shipped with grease holding the vertical O-rings in place. After cleaning, the O-rings don't hold, and are currently pinned in place with Kapton tape at the corners. SMI was able to avoid this scenario and procured half-dovetail grooves on the high vacuum</li> </ul> </li> </ul>

Lessons Learned— Successes	Description, Impacts, and Solutions
	<p>sample chamber.</p> <ul style="list-style-type: none"> <li>Increased interaction of this type can benefit future projects.</li> </ul>
Use of 3D printing for feasibility tests	<ul style="list-style-type: none"> <li>3D printing of small parts is a rapid and cheap method for evaluating and improving the design of interface components. Examples for ISR were mounts for phase plates and analyzer crystals, both of which are installed by hand in places with limited accessibility. 3D printing enabled feasibility tests without spending the time or money that would have been required for repeated metal fabrication.</li> </ul>

## 8.2 Potential Improvements

Lessons Learned Improvements	Description, Impacts, and Solutions
Design: interface expectations	<ul style="list-style-type: none"> <li>Responsibilities on either side of an interface need to be defined clearly to enhance efficiency. An example is the interface between beamline and utilities design. The required input from the beamline team to the utilities team was not articulated clearly, resulting in multiple requests for input in different formats.</li> </ul>
Early Definition of Technical Policies & Procedures and Engineering Standards	<ul style="list-style-type: none"> <li>Definition of technical policies &amp; procedures and engineering standards is needed early in a 4-year long MIE project to inform front end and beamline designs.</li> <li>The standards need to be consistent among all Photon Sciences Divisions and BNL lab-wide for maximum efficiency and safety.</li> </ul>
Underestimated mechanical design effort to support beamline IRRs	<ul style="list-style-type: none"> <li>Compared to NEXT estimates, additional mechanical design effort was needed for IRR documentation and as-built drawing releases (Vendor Item Drawings) for travelers and configuration documents requiring release numbers.</li> </ul>
Use in-vacuum motors only when necessary	<ul style="list-style-type: none"> <li>Make every effort to minimize the number of motorized/actuated degrees of freedom. For ISR, it was left to the vendor to choose between a long second crystal and a motorized short second crystal, in order to achieve a fixed-exit beam from the DCM. Specifying the former would have eliminated the need for an in-vacuum motor that is otherwise critical for the functioning of the entire beamline.</li> </ul>
Specification good practices	<ul style="list-style-type: none"> <li>Infrastructure that doesn't meet specification, or has been inadequately specified, has a trickle-down effect on component cost. Expect to spend money for ancillary equipment to rectify infrastructure shortcomings, which may not become apparent until testing activities begin.</li> <li>Require vendor design layouts to include locations, support, and/or cable routing for ancillary equipment (e.g., electronics and pumps).</li> </ul>
Beamline vacuum section design	<ul style="list-style-type: none"> <li>SMI Photon Delivery was broken into two beamline packages of about \$1.5M, which was a good size for a vendor bid and for using the small beamline team. However, the interface between the packages was placed in the middle of a vacuum section, leading to consternation with both vendors</li> </ul>

	<p>regarding who had the pumps, gauge sets, etc. in their scope of supply and how they could be responsible for vacuum performance across the boundary. Packages should always be separated at a vacuum section, with a gate valve ending one package and a bellows starting the next.</p> <ul style="list-style-type: none"><li>• Vacuum design should take the possibility of adverse events into consideration, but improbable events should not dictate the design. An example for ISR was the relative locations of bellows and gate valves, which were optimized for bellow failure, but not the much more likely need to vent and open vacuum chambers.</li></ul>
Vacuum standards	<ul style="list-style-type: none"><li>• Vacuum equipment standards should be codified as much as possible.</li><li>• Example: types of gate valves permitted in NSLS-II beamlines. The use of viton-sealed valves may be permitted, but the relevant policies are not clearly documented.</li></ul>

**Submitted by:**

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## ACRONYMS

APP	Advanced Procurement Plan
BHSO	Brookhaven Site Office
BNL	Brookhaven National Laboratory
CAM	Cost Account Manager
CD	Critical Decision
DCM	Double Crystal Monochromator
DOE	Department of Energy
EAC	Estimate At Complete
ES&H	Environment, Safety and Health
ESM	Electron Spectro-Microscopy beamline
EV	Earned Value
EVMS	Earned Value Management System
FXI	Full-field X-ray Imaging Beamline
FY	Fiscal Year
HR	Human Resources
I/O	Input/Output
IRR	Instrument Readiness Review
ISR	Integrated In-Situ and Resonant X-ray Studies
ISS	Inner Shell Spectroscopy beamline
IXS	Inelastic X-ray Scattering Beamline
MIE	Major Item of Equipment
M&S	Material & Supplies
NEXT	NSLS-II Experimental Tools project
NSLS-II	National Synchrotron Light Source II
OPC	Other Project Costs
PCR	Project Change Request
PPM	Procurement and Property Management
PS	Photon Sciences
QA	Quality Assurance
RSI	Requirement, Specification, and Interface
SEB	Satellite Endstation Building

SIX	Soft Inelastic X-ray Scattering beamline
SMI	Soft Matter Interfaces beamline
SOW	Statement of Work
TEC	Total Estimated Cost
TPC	Total Project Cost
TRF	Triple Rotation Flange
WBS	Work Breakdown Structure

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